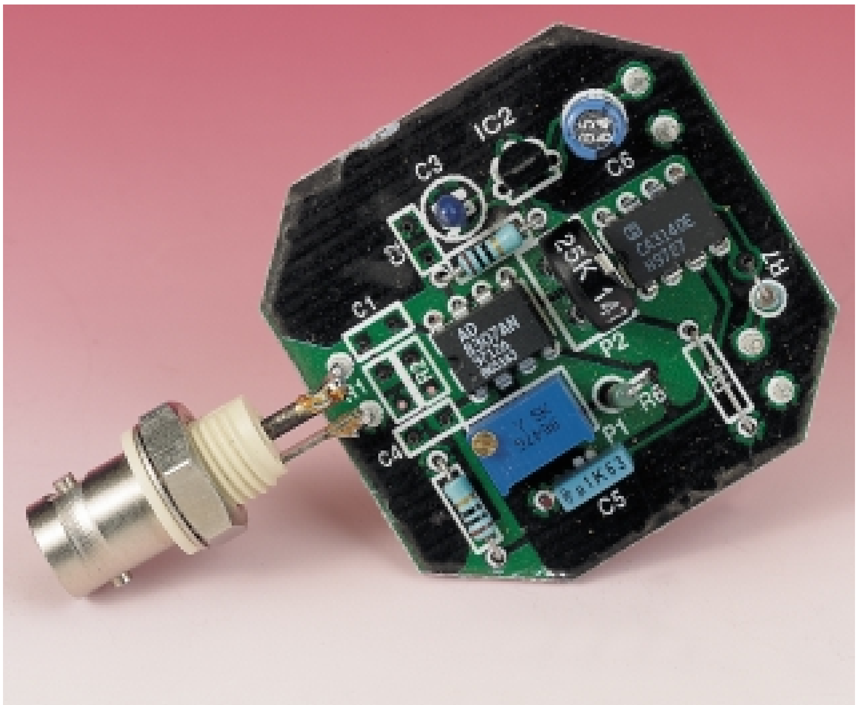
RF decibel meter

wideband with large measuring range



Some parameters

Frequency range	*100 kHz – 110 MHz with an error <1 dB*
	100 kHz – 200 MHz with an error ≤ 2 dB
Decibel range	*32 – 117 dBµ with an error at 10 MHz ≤ 1 dB*
Scaling	*10 mV dB^{-1}*
Input impedance	*50 Ω*

An RF decibel (or power) meter is an indispensable instrument in any radio workshop. Unfortunately, accurate, wideband models are fairly expensive, and home-constructed ones are generally not sufficiently sensitive and/or are very temperature-dependent. These drawbacks are overcome by a device from Analog Devices which has recently become available: a low-cost DC–500 MHz, 92 dB logarithmic amplifier that enables an accurate, not too expensive RF decibel meter to be constructed. A few small modifications make the meter also suitable for low-frequency measurements.

Design by P. Bolch

CIRCUIT DESCRIPTION

The circuit diagram of the decibel meter in **Figure 1** stands out by its simplicity, which is due to the Type AD8307 monolithic demodulating logarithmic amplifier, IC_1, from Analog Devices.

The measurand (quantity to be measured) is applied to pin 8 (INP) of IC_1 via input socket K_1 and capacitor C_1. The capacitor ensures that no direct voltage can reach the IC. The second input of the IC, pin 1 (INM) is linked to the earth line via capacitor C_4. The values of C_1 and C_4 are chosen to give a lower limit of the frequency range below 100 kHz.

Resistors R_1 and R_2 ensure that the input impedance of the meter is the usual value in RF equipment of 50 Ω. A parallel network is used to minimize any parasitic properties of the resistors. It is recommended to use SMT (surface mount technology) resistors.

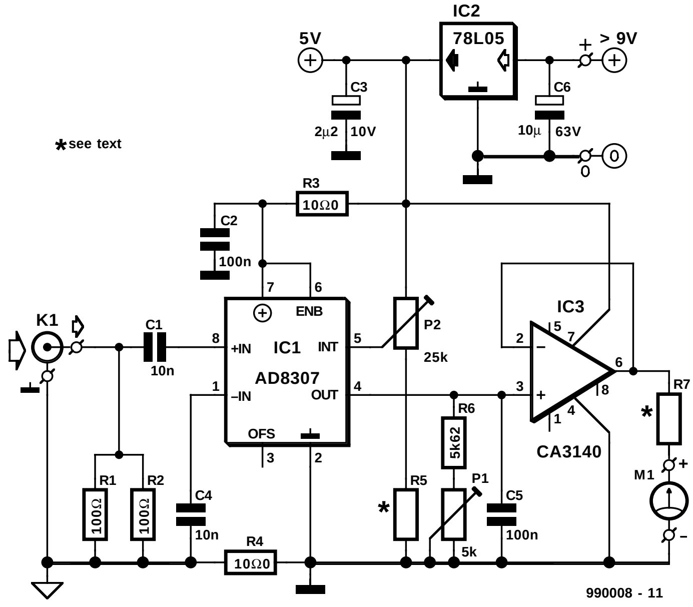


Figure 1. The circuit diagram of the decibel meter is centred on the AD8307 from Analog Devices.

Since the resistors are in parallel with the input terminals, any direct voltage present on the input signal will cause a potential drop across them. If this causes a problem, a coupling capacitor of about 0.02 µF may be inserted between the input socket and the resistors, but this will restrict the frequency range to about 30 MHz.

The output of IC_1 is essentially a current that causes a potential drop across a 12.5 kΩ internal resistor which is available at output pin 4. Series network R_6-P_1 is in parallel with the internal resistance to modify the scale factor, which is 25 mV dB^{-1} in the absence of an external circuit.

Capacitor C_5 averages the output signal to ensure a stable display. Its value depends on the application: a larger capacitance gives a more stable, but slow, display; a smaller value is recommended for fast sweeping.

Preset P_2 permits parallel shifting of the characteristic to give an attenuation of up to 14 dB or an amplification of up to 26 dB between the input socket and pin 8 of IC_1, provided that R_5 = 0. Resistor R_5 provides a narrowing of this preset range.

The purpose of resistor R_4 is to decouple the output of IC_1 from the remainder of the circuit and so enhance the response ratio of small signals.

Owing to the high output impedance of IC_1, buffer amplifier IC_3 is essential to enable a low-impedance load such as a moving-coil meter to be linked to the circuit.

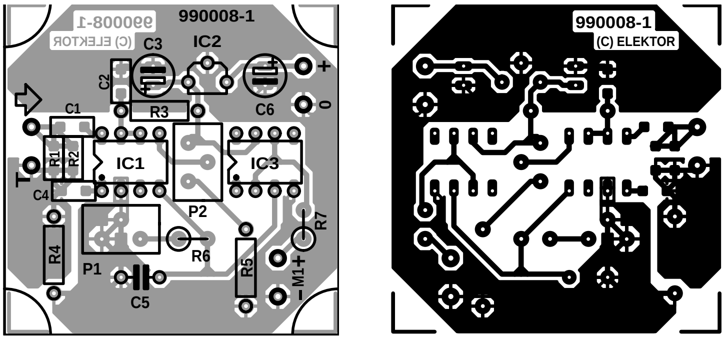
Regulator IC_2 ensures a stable supply line for IC_1. Low-pass filter R_3-C_2 reduces any interference on the supply line.

A small modification enables the circuit to be used as a low-frequency decibel meter. Resistors R_1 and R_2, as well as capacitors C_1 and C_4, are then not used. Instead, pin 8 of IC_1 is linked via a parallel network of a 10 µF, 10 V tantalum capacitor and a 4.7 kΩ resistor in series with a 680 pF capacitor to the input socket, while pin 1 is connected to earth via an identical series-parallel network. Also, capacitor C_5 must be replaced by a 1 µF, 10 V tantalum capacitor (+ve terminal to pin 4). Finally, a 1 µF, 10 V tantalum capacitor must be fitted between pin 3 of IC_1 (+ve terminal) and earth. When this modification is carried out, the meter is no longer usable as an RF decibel meter, of course.

DISPLAY

The display may be a digital multimeter, but, although this is accurate, it is not

Figure 2. The decibel meter is best built on this printed-circuit board which is, however, not available ready made.



Parts list

Resistors:
R_1, R_2 = 100 Ω, SMD
R_3, R_4 = 10.0 Ω
R_5, R_7 = see text
R_6 = 5.62 kΩ
P_1 = 5 kΩ (4.7 kΩ) multiturn upright preset potentiometer
P_2 = 25 kΩ multiturn upright preset potentiometer

Capacitors:
C_1, C_4 = 0.01 µF, SMD
C_2 = 0.1 µF, SMD
C_3 = 2.2 µF, 10 V, tantalum
C_5 = 0.1 µF. metallized polyester
C_6 = 10 µF, 63 V, tantalum

Integrated circuits:
IC_1 = AD8307AN (Analog Devices)
IC_2 = 78LO5
IC_3 = CA3140E

Miscellaneous:
K_1 = 50 Ω BNC socket for board mounting
Enclosure

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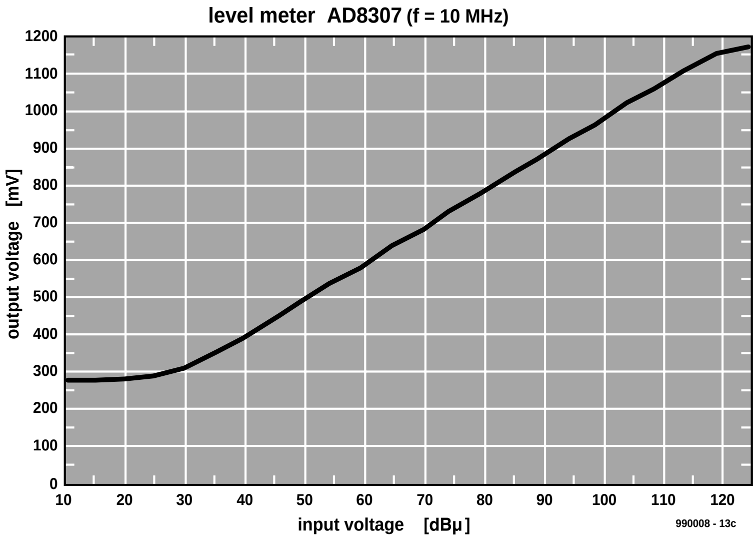

Figure 3. Transfer characteristic of the decibel meter at 10 MHz.

Level (dBµ)	Level (dBm)	$U_{o(10\,MHz)}$ (mV)	$U_{o(110\,MHz)}$ (mV)
10	–97	281	282
15	–92	282	283
20	–87	285	285
25	–82	294	294
30	–77	312	313
35	–72	353	356
40	–67	397	400
45	–62	450	450
50	–57	497	496
55	–52	550	544
60	–47	596	590
65	–42	650	641
70	–37	695	686
75	–32	750	737
80	–27	795	783
85	–22	847	833
90	–17	895	881
95	–12	948	933
100	–7	994	980
105	–2	1049	1033
110	+3	1090	1078
115	+8	1143	1132
120	+13	1185	1178
125	+18	1218	1188

The output at 200 MHz for an input of 99 dBµ is 948 mV
The output at 300 MHz for an input of 100 dBµ is 942 mV

easily calibrated.

A moving coil metering network with series resistor R$_7$ facilitates recognizing any drift such as encountered, for instance, during calibration, but does not make reading it easy.

Measurements with sweep frequencies can, of course, be displayed on an oscilloscope.

The decibel meter outputs a direct voltage that is directly proportional to the input signal. The display is calibrated in dBµ (decibel referred to 1 microvolt). The scale factor is 100 mV dB^{-1}, so that an input signal of 100 dBµ results in an output voltage of 1 V.

CONSTRUCTION

The meter circuit is best built on the printed-circuit board shown in **Figure 2**, but this is not available ready made. As mentioned earlier, some of the components should be SMDs (surface mount devices) as specified in the components list. If the circuit is constructed on prototyping board, standard components may, of course, be used. Keep all wiring as short as possible, however.

If operation up to 30 MHz only is needed, IC$_1$ may be inserted in a socket, but for use at higher frequencies the circuit should be soldered directly on to the board. This is best done after all other components have been fitted and the board has been checked thoroughly. This measure is to protect the AD8307, since this is not a cheap component.

Since the meter is an RF unit, it is clear that it should be fitted in an earthed metal enclosure. The power supply should, of course, not be fitted in the same enclosure. Another important aspect is that the 9–15 V supply voltage should be ‘clean’. It is advisable to use feedthrough capacitors at the power line inputs and measurement output.

CALIBRATION

The meter circuit should be calibrated with a suitable RF signal generator or, in an emergency, an AF signal generator with calibrated attenuator.

Apply a signal at a frequency of 10 MHz and a level of 60 dBµ (1 mV r.m.s.) to the input of the meter circuit. Using a digital multimeter, measure the voltage at pin 3 of IC$_3$, increase or reduce the output of the signal generator by exactly 10 dB and turn P$_1$ to cause a change in the multimeter reading of 100 mV. The absolute value of the output voltage is not significant.

Next, apply a signal at a level of exactly 60 dBµ to pin 8 of IC$_1$ and turn P$_2$ until the meter indicates 600 mV.

If the requisite equipment is available, the calibration process can be repeated at a number of frequencies for greater versatility of operation.

If a signal generator is not to hand, adjust P$_1$ until the resistance between its wiper and earth is 1383 Ω measured with a digital multimeter. Finally, adjust P$_2$ to obtain a voltage of 1.627 V at pin 5 of IC$_1$, again measured with a digital multimeter.

SOME PROPERTIES

Figure 3 shows the transfer characteristic of the decibel meter at 10 MHz. The measurement range with an error smaller than 1 dB extends from about 30 dBµ to around 115 dBµ. Over a large part of this range, the error stays well below 0.5 dB. The error rises rapidly outside the measurement range, which is typical of the conversion process in IC$_1$.

When the frequency is increased

(the well-calibrated prototype can be used up to 110 MHz), the transfer characteristic shifts slightly downwards, but retains the linearity shown in Figure 3. A number of characteristic values at 10 MHz and 110 MHz are given in Table 1.

If measurements over only a limited range are needed, the frequency-dependent slight shift of the transfer characteristic may be negated during the calibration so that a slightly more precise meter reading is obtained.

Measurements carried out with the prototype at frequencies of 200 Mhz and 300 MHz at a stable input level of 100 dBµ show that the circuit may be used without any problem at these frequencies.

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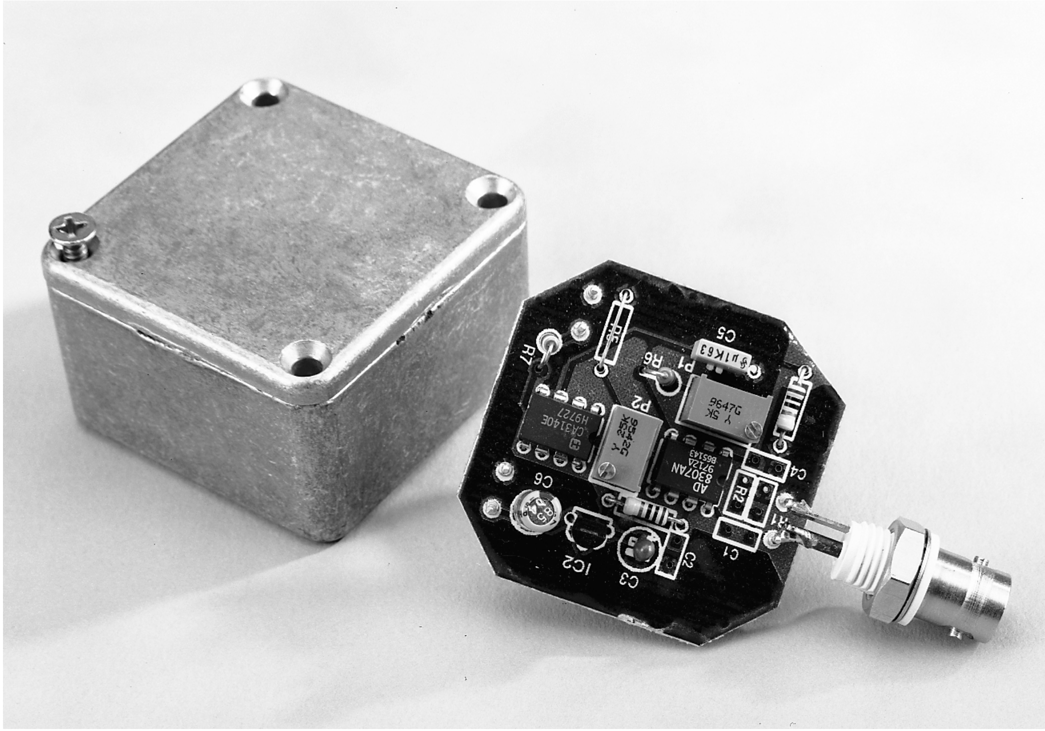

Figure 4. The finished prototype decibel meter.

AD8307

The Type AD8307 monolithic logarithmic amplifier is intended for a number of applications, among which

- *Conversion of signal level to decibel form*
- *Transmitter antenna power measurement*
- *Receiver signal strength indication (RSSI)*
- *Network and spectrum analysers (up to 120 dB)*
- *Signal level determination down to 20 Hz*
- *True decibel AC mode for multimeters*

Its operation is based on the progressive compression (successive detection) technique, providing a dynamic range of 92 dB to ±3 dB law-conformance and 88 dB to a tight ±1 dB error bound at all frequencies up to 100 MHz.

The device is very stable and easy to use. It needs a supply voltage of 2.7–5.5 V at 7.5 mA, corresponding to a low power consumption of 22.5 mW at 3 V. A fast-acting CMOS-compatible control pin can disable the AD8307 to a standby current of not more than 150 µA.

Each of the cascaded amplifier/ limiter cells has a small signal gain of 14.3 dB with a –3 dB bandwidth of 900 MHz. The input is fully differential at a moderately high impedance (1.1 kΩ in parallel with 1.4 pF).

The device provides a basic dynamic range extending from about –75 dBm (decibel referred to 1 mW) to around +17 dBm. A simple input-matching network can lower this range to –88 dBm to +3 dBm. The logarithmic linearity is typically within 0.3 dB up to 100 MHz over the central portion of this range, and is degraded only slightly at 500 MHz. There is no minimum frequency limit: the AD8307 may be used at audio frequencies down to DC.

The output is a voltage-scaled 25 mV dB^{-1}*, generated by a nominal current of 2 µA* dB^{-1} *through an internal 12.5 kΩ resistor. This voltage varies from 0.25 V at an input of –74 dBm (that is, the a.c. intercept is at –84 dBm, a 20 µV r.m.s. sinusoidal input), up to 2.5 V from an input of +16 dBm. This slope and intercept can be trimmed with external adjustments. For instance, with a 2.7 V supply, the output scaling may be lowered to 15 mV* dB^{-1} *to permit utilization of the full dynamic range.*

The AD8307 has good supply insensitivity and temperature stability of the scaling parameters. The combination of low cost, small size, low power consumption, high accuracy and stability, large dynamic range, and a frequency range from DC to UHF make it useful in numerous applications requiring the conversion of a signal to its decibel equivalent.

Further information on the Internet: www.analog.com/AD8307